3.2.3 Equilibrium

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	moment of force	
(b)	couple; torque of a couple	
(c)	the principle of moments	
(d)	centre of mass; centre of gravity; experimental determination of centre of gravity	
(e)	equilibrium of an object under the action of forces and torques	
(f)	condition for equilibrium of three coplanar forces; triangle of forces.	*M4.1, M4.2, M4.4*

(6) M - Calculate moments
(7) S - Apply the principle of moments
(8) C - Apply the principle of moments to forces at an angle.

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Lesson 5. Moments and equilibrium

STARTER: What do you remember about moments?
What is the principle of moments?
What does equilibrium mean?

line of action
pivot
mg

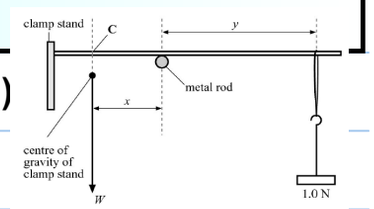
Extension: Mr and Mrs Smith have a combined mass of 150kg. Estimate the clockwise moment they cause.

Moment = **force** x **perpendicular** distance from **line of action** of the force and the **axis of rotation**

Principle of moments, for a body in rotational equilibrium, the sum of anticlockwise moments about any point = the sum of clockwise moments about that point

For an object in **equilibrium,** the **net force acting is zero** and the **net moment acting is zero**.

(6) M - Calculate moments
(7) S - Apply the principle of moments
(8) C - Apply the principle of moments to forces at an angle.

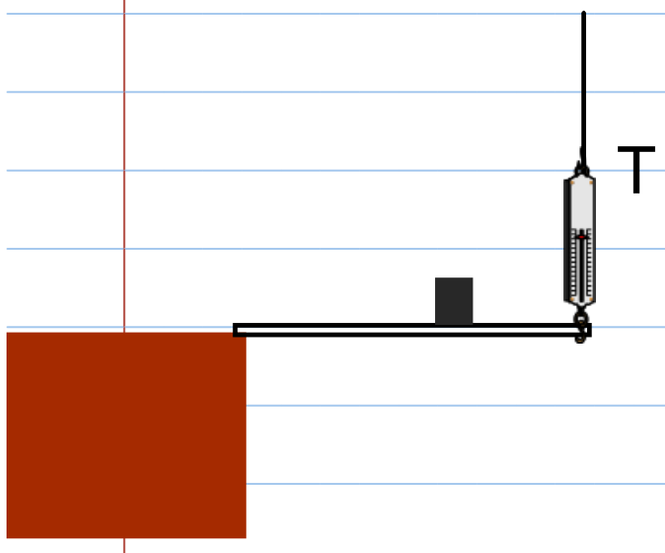


Demo: Find the mass of the clamp stand (M)

Step 1: Label the forces and the distances.

Step 2: Take moments about a point that T has a turning effect.

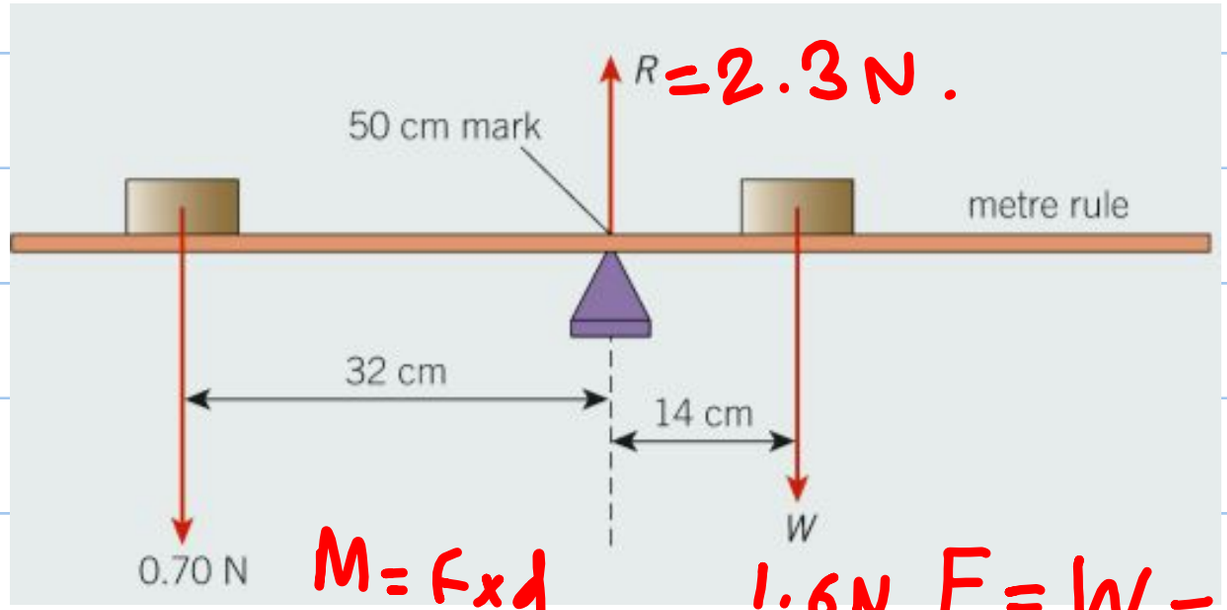
Step 3: Rearrange and calculate W. Then find m



Demo: What is the tension in the string (T)?

(6) M - Calculate moments
(7) S - Apply the principle of moments
(8) C - Apply the principle of moments to forces at an angle.

Quick check: Find the force R acting upwards from the pivot point of this ruler in equilibrium.

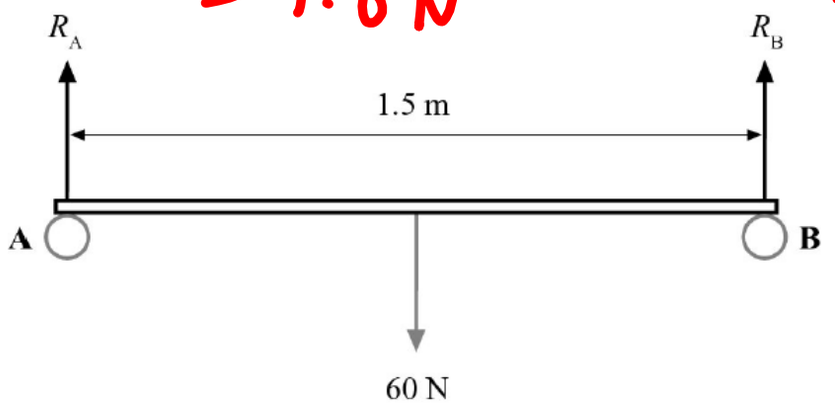


M = F x d
= 0.7 x 0.32
= 0.224 Nm

F = W = M / d = 0.224 / 0.14
= 1.6 N

Ex:

The diagram shows a uniform beam of length 1.5 m and weight 60 N resting horizontally on two supports.



a By taking moments about the support **A**, determine the force R_B at the support **B**. [3]

b Use your answer to a to calculate the force R_A at support **A**. [1]

(6) M - Calculate moments
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(8) C - Apply the principle of moments to forces at an angle.

Quick check: Hint - sketch a simplified force diagram

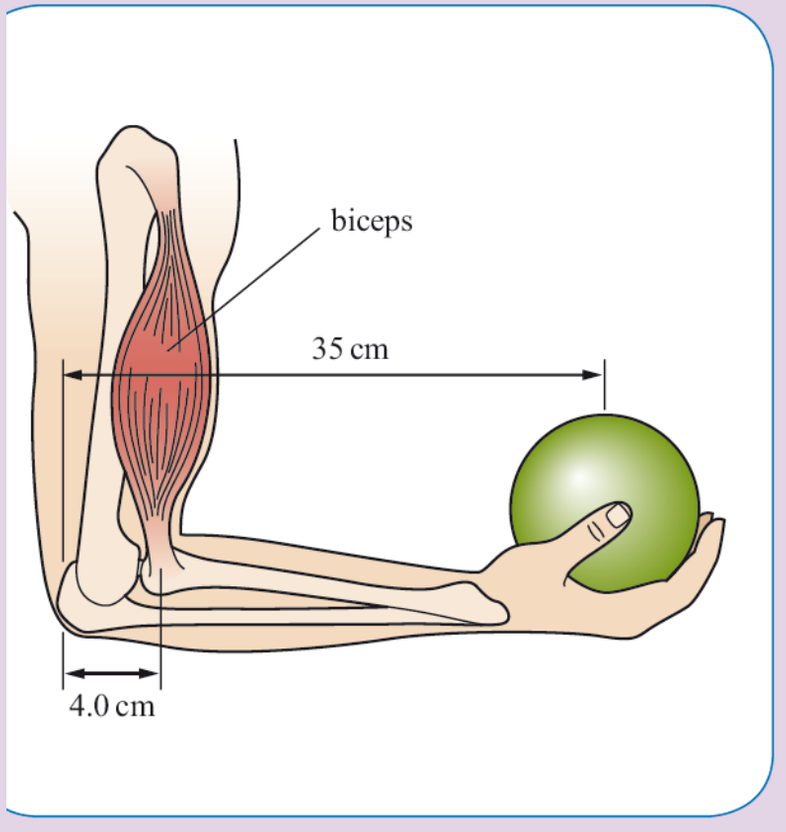
An object of weight 50 N is held in the hand with the forearm at right angles to the upper arm. Use the principle of moments to determine the muscular force F provided by the biceps, given the following data:

weight of forearm = 15 N

distance of biceps from the elbow = 4.0 cm

distance of centre of gravity of forearm from elbow = 16 cm

distance of object in the hand from elbow = 35 cm



(6) M - Calculate moments
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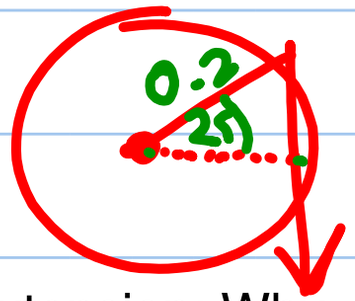
Force at an angle.

The pedal radius is 0.2m and the angle between it and the horizontal is 25 degrees.

1. Make a simple sketch.
2. What is the moment about **point a**?



Extension: Why might this not be the true answer?

$0.2 \cos 25 = 0.18m$

$M = F \times d$
$= 350 \times 0.18$
$= 63\ Nm$

(6) M - Calculate moments
(7) S - Apply the principle of moments
(8) C - Apply the principle of moments to forces at an angle.

Force at an angle: Quick check

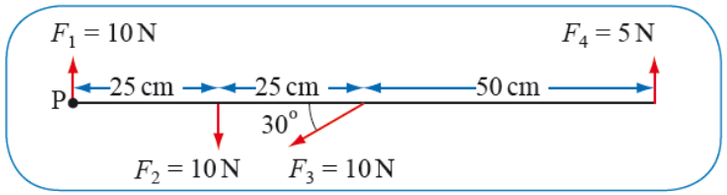
6 Figure 5.15 shows a beam with four forces acting on it.

a For each force, calculate the moment of the force about point P.

b State whether each moment is clockwise or anticlockwise.

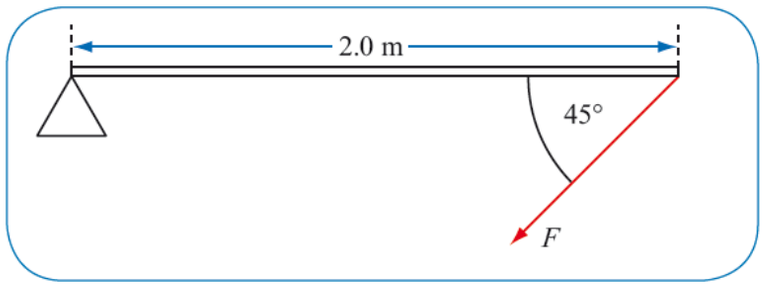
c State whether or not the moments of the forces are balanced.

Answer



7 The force F shown in Figure 5.16 has a moment of 40 N m about the pivot. Calculate the magnitude of the force F.

Answer



a, b F_1, 0 N m; F_2, 2.5 N m clockwise; F_3, 2.5 N m clockwise; F_4, 5.0 N m anticlockwise.

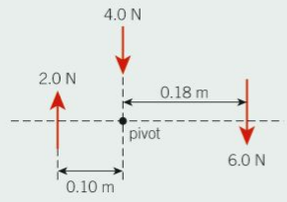
c Yes, the moments are balanced.

28.3 N ≈ 28 N

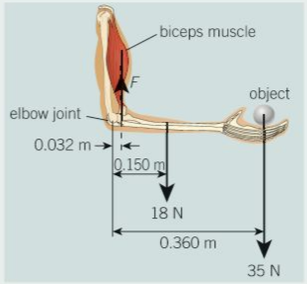
(6) M - Calculate moments
(7) S - Apply the principle of moments
(8) C - Apply the principle of moments to forces at an angle.

Summary questions

1 Calculate the moment from each force about the pivot in Figure 6. *(3 marks)*



▲ Figure 6

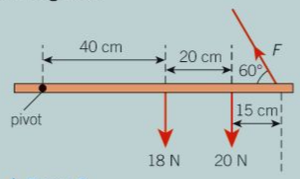


◀ Figure 7

2 Figure 7 shows a human forearm held horizontally and still. Calculate:
a the clockwise moment about the elbow joint; *(3 marks)*
b the force F in the muscle. *(3 marks)*

3 A uniform cylinder has height 10.0 cm and diameter 3.0 cm. The cylinder is placed with its circular base resting on a horizontal table. Calculate the maximum angle through which it can tip before it continues to fall by itself. *(3 marks)*

4 Calculate the magnitude of the force F in Figure 8. *(6 marks)*



▲ Figure 8

a, b F_1, 0 N m; F_2, 2.5 N m clockwise; F_3, 2.5 N m clockwise; F_4, 5.0 N m anticlockwise.

c Yes, the moments are balanced.

$28.3\,\text{N} \approx 28\,\text{N}$